International Journal of Electronics,
Communication & Instrumentation Engineering
Research and Development (IJECIERD)
ISSN(P): 2249-684X; ISSN(E): 2249-7951
Vol. 5, Issue 1, Feb 2015, 1-8

COMPARATIVE STUDY OF PAPR PERFORMANCES FOR DIFFERENT SUBCARRIER MAPPING TECHNIQUES IN SC-FDMA

SEEMA HANCHATE[1], S. A. BORSUNE[2] & SHIKHA NEMA[3]

[1]Assistant Professor, Department of Electronic and Communication, UMIT, SNDT University, Mumbai, Maharashtra, India

[2]Assistant Professor, Department of Electronics and Telecommunication, YTCEM, Maharashtra, India

[3]Professor, Department of Electronic and Communication, UMIT, SNDT University, Mumbai, Maharashtra, India

ABSTRACT

The rapid increasing demand on high data rates in wireless communications systems has arisen in order to support broadband services. The 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) aims at very high peak data rates such as 1 Gbps in local areas and 100 Mbps in wide areas. LTE has adopted Orthogonal Frequency Division Multiple Access (OFDMA) as downlink and Single Carrier Frequency Division Multiple Access (SC-FDMA) as uplink for multiple access schemes. SC-FDMA has drawn great attention as an attractive alternative to OFDMA, especially in the uplink communications where lower peak-to-average power ratio (PAPR) greatly benefits the mobile terminal in terms of transmit power efficiency and reduced cost of the power amplifier. It has been adopted as the uplink multiple access scheme in 3GPP Long Term Evolution (LTE), or Evolved UTRA (E-UTRA). The SC-FDMA is almost similar to that of OFDMA systems in its complexity and it provides same throughput as that of OFDMA. In this paper give an overview of SC-FDMA. Also we analyze the effect of two subcarrier mappings used in SC-FDMA i.e. Localized FDMA (LFDMA) and Interleaved FDMA (IFDMA) on PAPR of SC-FDMA and makes a comparison of the two subcarrier mapping techniques. We do comparative study of PAPR characteristics using the complementary cumulative distribution function (CCDF) of PAPR.

KEYWORDS: L-FDMA, SC-FDMA, PAPR, OFDMA, DFDMA

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has been employed in many fields because of high channel efficiency and greater capability to resist fading. A major drawback of OFDM transmission,however, is its high Peak to Average Power Ratio (PAPR) which increases operational requirements of the Linear Power Amplifier in the transmitting equipment leading not only to an increased cost but also an increased power consumption which is not desired especially at the uplink transmitter, the User Equipment (UE).[1] Single carrier frequency division multiple access (SC-FDMA), a modified form of Orthogonal FDMA (OFDMA), is a promising technique for high data rate uplink communications in future cellular systems. SC-FDMA has similar throughput performance and essentially the same overall complexity as OFDMA. A principal advantage of SC-FDMA is the peak-to-average power ratio (PAPR), which is lower than that of OFDMA. SC-FDMA is currently a strong candidate for the uplink multiple access scheme in the Long Term Evolution of cellular systems under consideration by the Third Generation Part-nership Project (3GPP).

In this paper, we give an overview of different subcarrier mapping approach on PAPR of SC-FDMA. We have also done comparative analysis of all subcarrier methods of SCFDMA in terms of PAPR.

This paper is organized as follows: Section 2, gives system Configuration of Single Carrier FDMA. Section 3, gives different subcarrier mapping techniques and it also presents case. Section 4, performances of PAPR for in each subcarrier mapping in SC-FDMA system is simulated in MATLAB. Finally, some concluding remarks are given.

2. SYSTEM CONFIGURATION OF SC-FDMA

Figure 1 shows a block diagram of an SC-FDMA system. SC-FDMA can be regarded as DFT-spread orthogonal frequency division multiple access (OFDMA), where time domain data symbols are transformed to frequency domain by DFT before going through OFDMA modulation [4].

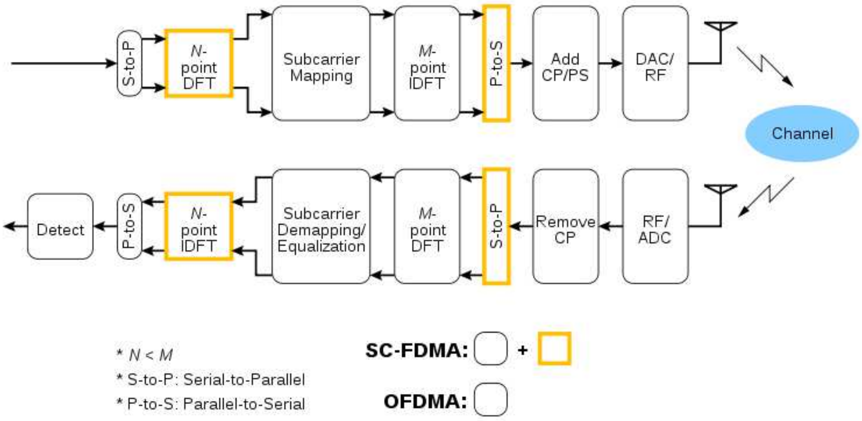


Figure 1: Block Diagram of SC-FDMA & OFDMA

A principal advantage of SC-FDMA is PAPR which is lower than that of OFDMA. In SC-FDMA system, each modulated symbol is transmitted serially in a wide-band channel which causes Inter-Symbol Interference (ISI) at the base station (BS). The BS employs Frequency Domain Equalization (FDE) to cancel ISI. This configuration is attractive in cellular system because it reduces linear amplification in mobile device at the cost of increasing signal processing complexity at the BS.

The signal processing block diagram of SC-FDMA and OFDMA is shown in Figure 1 and 2. For each user the sequence of bits is mapped to a complex constellation (BPSK, QPSK, M-QAM). These different users are assigned to different frequency band. The assignment is done in subcarrier mapping block. The receiver includes one subcarrier de-mapping/equalization and two DFT/IDFT blocks. The main difference between OFDMA and SC-FDMA is the DFT precoder at the transmitter. After mapping data bits into modulation symbols into block of N symbols, an N-point DFT transforms these symbols in time domain into frequency domain. The frequency domain samples are then mapped to a subset of M-subcarriers where M is greater than N. An M-point IFFT is used to generate the time-domain samples of these subcarriers. Similar to OFDMA a Cyclic Prefix (CP) is inserted between two blocks in order to prevent Inter-Block-Interference (IBI) due to multipath propagation.

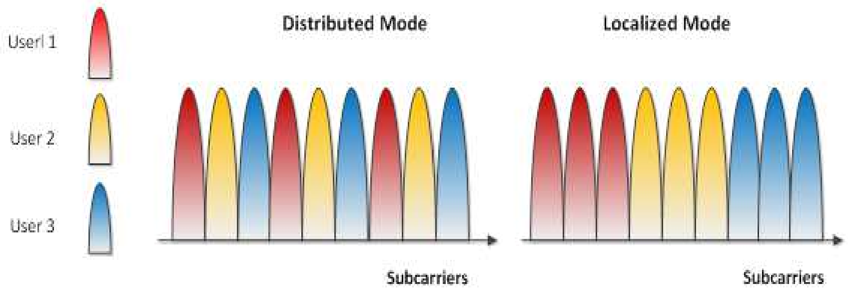
Since each data symbol is DFT transmitted before mapping to subcarriers, hence the SC-FDMA is called DFT-precoded OFDMA. In OFDMA, each data symbol is carried on a separate subcarrier. In SC-FDMA, multiple subcarriers carry each data symbol. As each data symbol is spread over multiple subcarriers, SC-FDMA offers spreading gain or frequency diversity gain.

3. SUBCARRIER MAPPING

In SC-FDMA, multiple access is achieved by allocating non-overlapping frequency band to different users. This is implemented by assigning zero IDFT coefficients in the position of the other users (in the frequency domain before IDFT). Therefore, at the receiver the other users interference can be removed after DFT by zeroing the frequency band allocated to the other users. DFT output of data symbols is mapped to a subset of subcarriers, a process called subcarrier mapping. The subcarrier mapping assigns DFT outputs to selected subcarriers. Subcarrier mapping as shown in Figure 2, can be classified into two types: can be classified into two types:

- Localized mode
- Distributed mode

In localized SC-FDMA each terminal uses a set of adjacent subcarrier to transmit symbols, thereby confining them to only a fraction of system bandwidth. In distributed SC-FDMA, the subcarriers used by a terminal are spread over the entire bandwidth. One realization of distributed SC-FDMA is interleaved FDMA (IFDMA) where occupied subcarriers are equally spaced from each other. Localized SC-FDMA has lower PAPR than distributed SC-FDMA and is currently employed in LTE uplink.



Localized Distributed

Figure 2: Subcarrier Mapping Modes: Localized and Distributed

The transmitter of an SC-FDMA system converts a binary input signal to a sequence of modulated subcarriers. A block is the time used to transmit all of subcarriers once. The transmitter next groups the modulation symbols into blocks each containing N symbols. The first step in modulating the SC-FDMA subcarriers is to perform an N-point discrete Fourier transform (DFT), to produce a frequency domain representation of the input symbols. It then maps each of the N DFT outputs to one of the M orthogonal subcarriers that can be transmitted. If all terminals transmit N symbols per block which is an integer submultiple of M, the system can handle Q simultaneous transmissions without co-channel interference, where Q is M/N. The result of the subcarrier mapping is the set of complex subcarrier amplitudes, where N of the amplitudes are non-zero. As in OFDMA, an M-point inverse DFT (IDFT) transforms the subcarrier amplitudes to a complex time domain signal.

There are two methods to choose the subcarriers for transmission as shown in Figure 6. In the distributed subcarrier mapping mode, DFT outputs of the input data are allocated over the entire bandwidth with zeros occupying in unused subcarriers, whereas consecutive subcarriers are occupied by the DFT outputs of the input data in the localized subcarrier mapping mode. The distributed subcarrier mapping mode of SC-FDMA is referred to as distributed FDMA (DFDMA) herein and the localized subcarrier mapping mode of SC-FDMA is referred to as localized FDMA (LFDMA) herein. The case of M=Q·N for the distributed mode with equidistance between occupied subcarriers is called Interleaved FDMA (IFDMA). An example of SC-FDMA transmit symbols in the frequency domain for N=4, Q=3 and M=12 is illustrated in Figure 3.

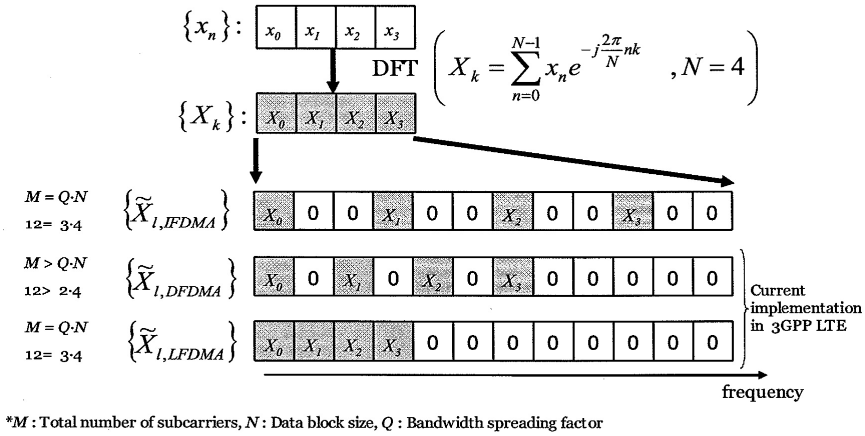


Figure 3: SC_FDMA Transmit Symbols

3.1 Peak to Average Power Ratio

When the signals of all the sub-carriers are added constructively, the peak power can be the number of sub-carriers times the average power. When a high PAPR OFDM signal passes through a nonlinear device, it may cause in band distortion and undesired spectral spreading. Thus, handling occasional large peaks leads to low power efficiency. Therefore, how to find a solution to reduce high PAPR effectively is one of the most important implementation issues in OFDM communications.[8][9]

The PAPR is defined as the ratio of peak power to average power of transmitted signal .

$$PAPR = \frac{\max_{n=1}^{N}\left(|z_n|^2\right)}{\frac{1}{N}\sum_{n=1}^{N}|z_n|^2}$$

We define here bandwidth efficiency, a parameter that indicates how efficiently the given modulation technique uses the bandwidth. The bandwidth efficiency will be represented by a number between 0 and 1. The modulation technique occupying a bandwidth as dictated from the Nyquist criterion has the highest bandwidth efficiency and equals to 1. The PAPR depends on the bandwidth efficiency and when the bandwidth efficiency increases the PAPR also increases. When the number of sub-carriers increases the PAPR and bandwidth efficiency also increases. The number of sub-carriers plays the role of “mediator” between the PAPR and bandwidth efficiency.

Disadvantages of Higher Value of PAPR

- Nonlinear distortion in the high power amplifier.
- Reduction of the power efficiency

- Increasing the complexity of the ADC and DAC.

The cumulative distribution function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. Normally, the complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold. The CDF of the PAPR of the amplitude of a signal sample is given by

F(z) = (1- exp(- z2)) N

where z be the magnitude of complex sample

CCDF of PAPR = 1 - F(z)

4. SIMULATION RESULTS

Simulation have been carried out for LFDMA and IFDMA for different values of M in QAM modulation scheme. In Figure 4, the PAPRs and their CCDF for Localized SC-FDMA and Interleaved SC-FDMA is presented. Here, 4-QAM, 32-QAM, 64-QAM and 256-QAM used for SCFDMA system with number of subcarriers (N) = 256. It can be seen from the simulation result that PAPR performance of the SCFDMA varies depending on the subcarrier mapping method. The performance of SCFDMA is degraded as M increases. Moreover Interleaved SCFDMA transmission mode has low value of PAPR as compared to L-FDMA.

CONCLUSIONS

In this paper, The advanced technology behind the LTE uplink transmission that is SC-FDMA is analysed specifically. A comparison between the LFDMA and IFDMA is also done and different subcarrier mapping schemes will also result in different PAPRs. In conclusion, the SC-FDMA systems with IFDMA and LFDMA have a better PAPR. The value of PAPR of SCFDMA is increased as M increases IFDMA has a slightly better performance in terms of PAPR than LFDMA. Although the IFDMA has a lower PAPR than LFDMA, the LFDMA is usually preferred for implementation. It is attributed to the fact that subcarriers allocation with equi-distance over the entire band (IFDMA) is not easy to implement. Since IFDMA requires additional resources such as guard band and pilots.

ACKNOWLEDGEMENTS

A large number of people generously contributed to this paper. We are thankful to all of them for their valuable suggestions.

REFERENCES

1. H. G. Myung, J. Lim, and D. J. Goodman, "Peak-to average Power Ratio of Single Carrier FDMA Signals with Pulse Shaping", Proc. IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) Sep 2006.

2. Mohamed Salah*, Gamal Abdel-Fadeel**, and Zaki B. Nossair, “Peak to Average Power Ratio Reduction in Single Carrier OFDMA Systems” 13th International Conference on AEROSPACE SCIENCES & AVIATION TECHNOLOGY, ASAT- 13, May 26 – 28, 2009.

3. T.Jiang and Y.Wu, “An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals,”

IEEE Transactions on Broadcasting, Vol.54, No.2, June 2008, pp.257-268.

4. Hyung G. Myung Junsung Lim David J. Goodman, “Peak-To Average Power Ratio of SC-FDMA signal without pulse shaping”, 17th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications 2006.
5. Dov Wulich, Lev Goldfeld and Gill R. Tsouri, “Peak-To Average Power Ratio in Digital communication”, 13th International Conference on AEROSPACE SCIENCES & AVIATION TECHNOLOGY, ASAT- 13, May 26 – 28, 2009.
6. A. Ghassemi and T. A. Gulliver, “Low-Complexity Distortionless Techniques for Peak Power Reduction in OFDM Communication Systems”, Journal of Computer Networks and Communications Volume 2012.
7. Peyali Choudhury, Achala Deshmukh, “Comparison and analysis of PAPR reduction techniques in OFDM” IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), volume 4 January 2013.
8. Lin Chen, and Xuelong HU, ‘‘ Research on PAPR Reduction in OFDM Systems’’, JOFCIS December 2010, pp.3919-3927.
9. Sheng- Ju Ku, and Chin -Liang Wang, ‘‘A Reduced complexity PTS Based PAPR Reduction Scheme for OFDM Systems, IEEE transactions on wireless, Vol. 9, NO. 8, August 2010, pp. 2455-2460.

APPENDICES

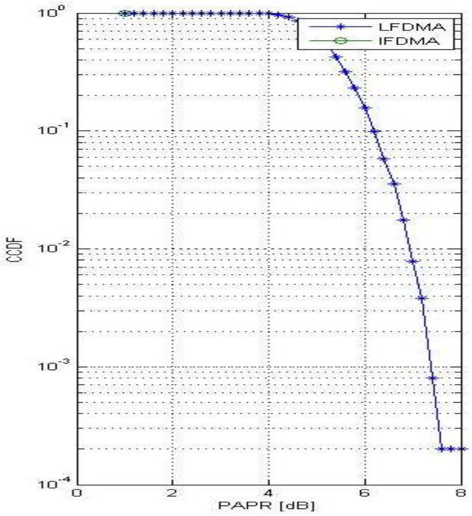


Figure 4(a): M=4

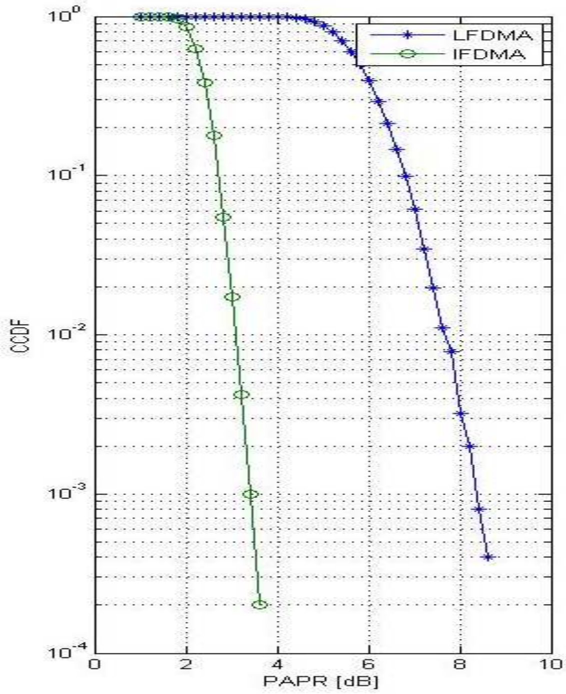


Figure 4(b): M=32

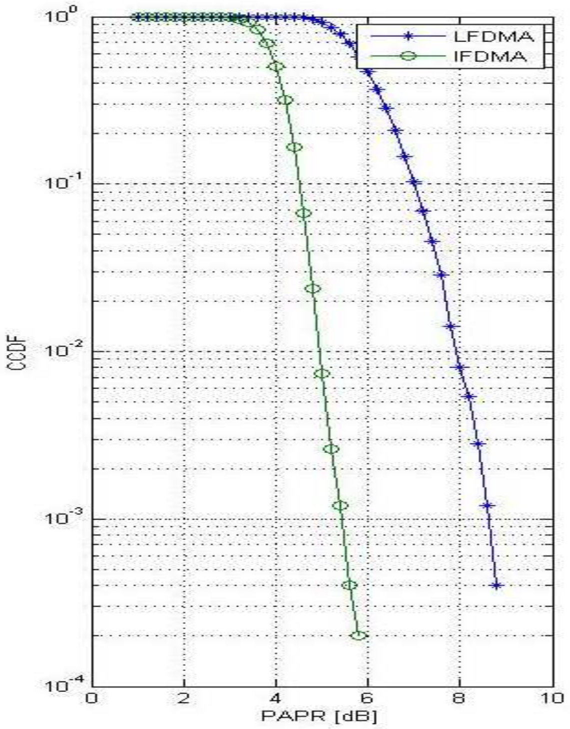


Figure 4(c): M=64

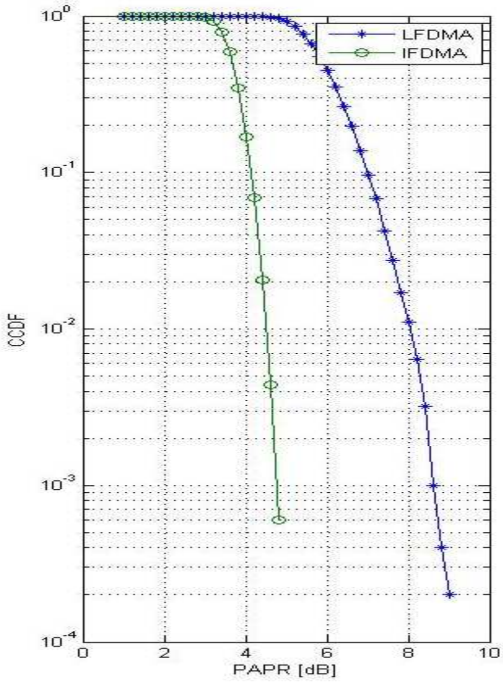


Figure 4(d): M=256

Figure 4: PAPR Performances for Different Number of Allocated Subcarriers

AUTHORS DETAILS

Prof. Seema M. Hanchate received Master of Engineering from Shivaji University, Maharashtra and is working as Asst. Prof. in Electronics & Communication Department at Usha Mittal Institute of Technology, SNDT Women's University, Mumbai. She has working experience of 16 years in teaching.

Prof. S. A. Borsune received Master of Engineering from Mumbai University, Maharashtra and is working as Asst. Prof. in Electronics & Telecommunication Department at Yadavrao Tasgaonkar College of Engineering and Management, Mumbai. She has working experience of 12 years in teaching.

Dr. Shikha Nema received PhD, Electronics and Telecomm. from MANIT, Bhopal and is working as Prof. in Electronics & Telecommunication Department at Usha Mittal Institute of Technology, SNDT Women's University, Mumbai. She has working experience of 15 years in teaching and 4 years in Industry.